Letters to the Editor.

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Action of Cutting Tools.

PROF. F. G. COKER has been good enough to send me a copy of his paper on the above subject, together with the discussion which followed its reading before the Institution of Mechanical Engineers. I will (with your permission) take this opportunity of thanking him and of adding a few remarks to my letter to NATURE of August 26 of this year.

I had not, when that letter was written, a copy of the Proc. R.S. paper of 1881 at hand, and was not certain as to how far the experimental processes preceding its production were described. On re-reading, however, I see that the experimental part was omitted, and I may here state that the force on the tool was measured by a dynamometer of the type shown diagrammatically in Fig. 1, and that it was found that for cuts of similar section the force required was very nearly proportional to the cross-section of the strip removed. This of course is equivalent to the statement that the same amount of work will remove the same volume of material whether the shavings are thick or thin, provided that they are similar.

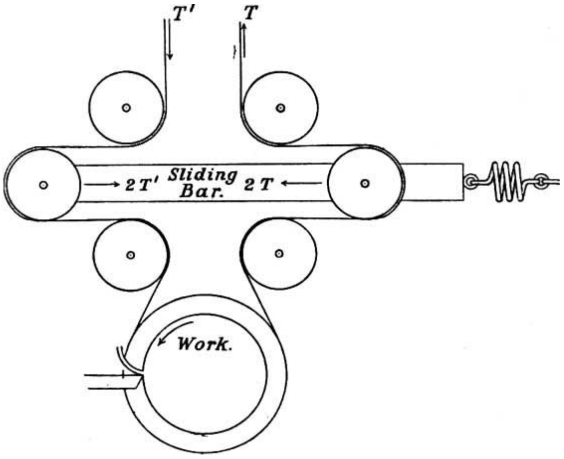

FIG. 1.—Diagrammatic sketch to show the action of dynamometer used for measuring the force on tool, T and T' being the tensions of the two parts of the driving belt. The force acting on the sliding bar is $2(T-T')$. This is balanced by the extension of the spring. Hence the movement of the bar, in conjunction with the known diameter of the work, gives (when corrected for the friction of the pulley, etc.) a measure of the force acting on the tool.

This dynamometer, which recorded the force automatically on paper moving with a velocity proportional to that of the cut, worked satisfactorily when the cutting speed was suitably chosen, though I should not use the same pattern were I again to embark on such investigations.

The materials on which the experiments were made included, besides the ordinary metals, others easier to deal with in a lathe worked by foot, and of these clay was found to be the most useful, for, according to the state of dryness to which it was brought, its behaviour under the action of the tool could be made to resemble that of any sort of metal, hard or soft, and at the same time cuts of easily measurable thickness could be taken with comparatively small forces.

While referring to the subject of material, I may mention a matter which seemed to me rather surprising. I wished to see whether it would be possible to face up a speculum casting in the lathe in order to save time in the preliminary grinding. Speculum metal, as is well known, is very brittle, but by taking a broad cut of extreme thinness with a dead-hard steel tool, continuous shavings were produced which looked like ribbons of grey satin. It was only while the edge of the tool was perfect that the cut was satisfactory, and this condition rarely lasted long enough to cover a speculum two inches in diameter.

With regard to Prof. Coker's paper, the only objection I have to make is that it has no reference to the action of cutting tools. The polarised-interference bands are evidence of elastic strain. They might be maintained indefinitely when the tool was stationary if the applied force was just insufficient to produce further rupture, and would disappear when that force was removed.

The elastic deformation, though interesting, has nothing to do with the special action of the tool, the essential function of which is to cause destructive strain throughout a small region near its edge while having no permanent effect on the body of the work.

The real interest in the action of a cutting tool is confined to the plane AB (Fig. 2) along which destructive shear takes place and a very short length of the material which forms the shaving—together with that part of the tool in contact with it.

The internal structure of a shaving closely resembles that of slate, the principal plane of cleavage being parallel to AB of Fig. 2, and the angle which this plane makes with the direction of the cut is modified by, and may be said to depend on, the angle which the face of the tool makes with the same direction and the mutual coefficient of friction between the tool and the material on which it operates.

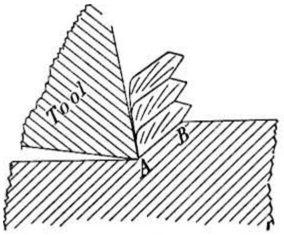

FIG. 2.—Action of a cutting tool, showing the principal and secondary planes of cleavage.

The action of the tool is always discontinuous and quasi-periodic, the period being determined by the travel required to extend the destructive shear from A to B. The period, therefore, is proportional (among other things) to the depth of the cut.

From this it may be seen that, in addition to the principal planes of cleavage, secondary and slightly differently inclined cleavages occur before the shearing across AB is complete. This was well shown in the polished and etched sections[1] referred to in the 1881 paper, and can also be recognised in the accompanying photographs (Figs. 3 and 4), though not quite so clearly.

The normal force on the tool during each period tends to expand (like rivet heads) the base of the strata which press against it, and this action causes the shaving to curl: the frictional force (parallel to the face of the tool) tends, on the other hand, to drag the base of strata towards the cutting edge, and thus to keep the shaving straight.

The shape of the cross-sections of a shaving is often rather peculiar, but is a definite function of the shape of the tool and of the properties of the material from

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[1] The earliest application of "etching" for the purpose of rendering the structure of a metal visible was, I suppose, the "crowning" of twisted gun-barrels, etc.

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which it is cut. It may be defined shortly as the projection on the plane of the section of the line bounding the area of destructive shear. This line will be in advance of the face of the tool by a distance proportional to the thickness of the cut at the point under consideration (see Fig. 5).

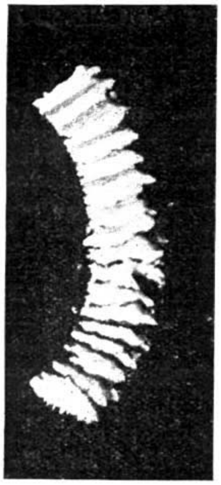

FIG. 3.

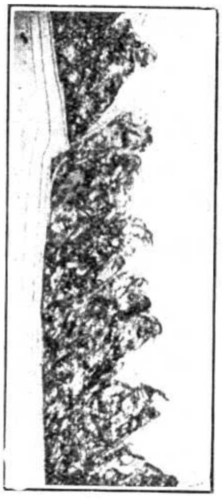

FIG. 4.

FIG. 3.—Shaving from a block of paraffin. At the temperature at which the cut took place, the paraffin behaves much like a sample of cast iron.

FIG. 4.—Longitudinal section of a similar shaving. The paraffin shaving was embedded in soap, sectioned in a microtome, and mounted in castor oil.

The shaving is always shorter than the length of the cut from which it was taken, and if α and β are respectively the angles which the principal plane of cleavage and the face of the tool make with the normal to the surface of the cut, it is easy to see that the ratio of the lengths is $\cos\alpha/\sin(\alpha+\beta)$.

Lubrication has an extraordinary effect in the cutting of certain materials. With brass and gun-metals no lubrication is required, but for steel, and also for such metals as soft copper and pure aluminium, clean cutting is impossible without it. Glass cutting with steel tools also requires a lubricant, for which purpose turpentine or petroleum are generally chosen.

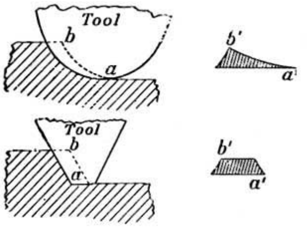

FIG. 5.—Relation between the cross-section of the cut, *ab*, and that of the shaving produced, *a'b'*.

I remember, in a correspondence with Sir G. G. Stokes on this subject, mentioning that even the presence of turpentine vapour had a noticeable effect. There can, I think, be little doubt that films of lubricant (of molecular thickness it may be) pass not only over the active part of the tool, but also penetrate along the planes of cleavage in the shaving itself.

A. MALLOCK.

9 Baring Crescent, Exeter.

One Possible Cause for Atmospheric Electric Phenomena: A Reply.

IF Sir Oliver Lodge will turn up his copy of NATURE for January 21, 1904 (Vol. 69, p. 270), he will find that I made there the identical suggestion for the origin of the earth's negative charge which he makes in NATURE of October 14, p. 512. The explanation is, however, unsatisfactory for a number of reasons, the chief of which may be stated shortly as follows:

To maintain the current from the earth into the atmosphere, it would be necessary for 2000 negative electrons to be shot into each square centimetre of the earth's surface every second. But beta rays ionise the air through which they pass, and according to recent theoretical work it appears that beta rays, no matter what their velocity may be, produce more than 40 pairs of ions along each centimetre of their path in air at atmospheric pressure. Thus in each cubic centimetre of air near the earth's surface 80,000 pairs of ions would be produced per second. But we know from actual measurements extending from the equator to the polar regions that only 4 or 5 are so produced and all these can be accounted for by known radiations.

Sir Oliver suggests that "the beta particles would be magnetically inveigled towards the poles, where they might descend with down currents." This suggestion has been made previously, and it is easy to show that it offers no way out of the difficulty although the demonstration is too long to be given here.

G. C. SIMPSON.

October 17.

The Green Ray at Sunset and Sunrise.

IN NATURE of October 14, p. 513, Prof. Alfred Porter maintains that there are two distinct phenomena which go under the name of the green flash, and that the one most usually seen is an after image in an eye fatigued by the red light of the sun. I have seen the green ray many times in this country and in the tropics, and the phenomenon as I have seen it is always exactly the same; I am quite convinced in my own mind that it is not due to eye fatigue, for the appearance at sunrise is precisely the same as that at sunset; I have seen it a number of times at sunrise, and the first time I ever saw it was at sunrise when I was not looking out for it. I have, moreover, examined the setting sun with binoculars and with a telescope; when the sun has very nearly set, but before the appearance of the green ray proper, the upper edge has a very irregular shape owing to refraction effects, sometimes resembling flames; the tops of these "flames" gradually become bright green and the colour spreads downwards till the whole of the minute remaining part of the disc becomes green. To any one who has examined the green ray with a telescope at sunset, and has seen it with the naked eye at sunrise, it seems inconceivable that it can be due to eye fatigue.

C. J. P. CAVE.

Stoner Hill, Petersfield,
October 21.

As the green segment continues to be debated, permit me to put a few facts on record. I have often in Egypt watched the sunrise light descending the western hills, and when the edge of the shadow reached me, turned to view the sun. The first appearance of the sun is a blue segment, changing to green, and then to white. This is exactly the converse of the colours of the sunset segment; as the rising light cannot be due to an after-image, no more is the setting light. Moreover I have never seen the green light shift about, as an after-image does, by movement of the eye; it is always exactly on the segment.

Further, I often have protracted the sunset blue by walking up a slope, and so keeping it in view, on and off, as long as I go upward. The least distance

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